GHG Emission Trends of the Internet in Germany

1. Internet.CO_2?

1.1 The Internet is on the Agenda

Promising new economic potentials and the vision of creating new businesses and jobs have made the internet a first priority subject among policymakers. Not long ago EU leaders decided to get the whole EU on the net. And the German minister of science and education announced that every school and every student in Germany should receive a portable computer and access to the internet.

Growth rates are astounding: the number of internet users in Germany is currently rising by about 50 % every six months. Internet experts predict that, by the end of 2001, Germany will have about 30 million private users. Only two years later, 60 million users and thus three out of four Germans will be online. E-commerce (B2C and B2B) is expected to be the fastest growing business, expanding its sales from 2.9 billion Euro in 1999 up to 65 billion until 2005 (Struve, 2000). The use of electronics and internet in offices is also rising at a notable speed.

1.2 But What About the Environment?

However, there might be a downside to this success story: is the exploding use of the internet in reality a Trojan horse that is boosting our electricity consumption and thus will lead to immense additional CO_2 emissions and other environmental problems?

An article by Peter Huber and Mark Mills in the Forbes! Magazine (May, 1999) seemed to deliver strong evidence for such an assumption. The authors concluded that even today the making and running of computers and internet equipment use more than 13% of the USA's electricity consumption. They further predicted that this figure would eventually rise to around 50 % of total electricity consumption. This was a strong message that caused concerns not only in the US, but also in Germany. Could it be that electricity shortages and a dramatic need for new power stations should be a main consequence of the booming internet use?

The scientific debate in the USA, however, quickly arrived at a more realistic picture. Instead of 13%, a mere 2 to 3% of the US's electricity consumption are currently needed for the use and construction of computers. Furthermore, growth rates are assumed to be slower than foreseen by Huber and Mills (Koomey et al., 1999; Kawamoto et al., 2000; Koomey, 2000). As it turned out, the basis for the Forbes! article was a report by Mill for a coal lobby group, which was intended to demonstrate the public that more electricity and more coal-fired power plants were essential for economic development (Lovins, 2000, Romm, 1999). Experts in electricity end-use analysis showed that Huber and Mills had used exaggerated figures for the electricity demand of PCs, web-servers, and mainframe computers used by E-commerce companies. Furthermore, Huber and Mills did not take into account that one server normally hosts more than one web-site, and that not all electricity use of PCs is attributable to the internet (Koomey et al., 1999).

Finally, data analyses of electricity productivity in the US showed that in "the immediate pre-internet era (1992-1996), GDP growth averaged 3.2%, while energy demand grew 2.4%. In the internet era (1996-2000), GDP growth is averaging over 4% a year, while energy demand is growing only 1%" (Romm, 1999).

Does this mean that there is no problem? Is it possible to transfer these findings to the European situation at the dawn of the internet age, with quite different modes of power consumption and supply? Can we trust that energy efficiency will compensate for the exploding use of computers?

1.3 Introduction to our Analysis

In our analysis, we will provide a brief estimate of the situation, the prospects of the internet use and its projected electricity consumption in Germany. We are acutely aware that a lot of the data is unclear or simply missing. Therefore, this can only be **a first attempt at showing probable ranges of development**. The purpose of the attempt is:

- first, to clarify the potential relevance of the internet for electricity consumption and today's as well as tomorrow's emissions; and

- second, to explore the needs for and the potentials of policy action to prevent negative impacts of the internet boom on power consumption and emissions. This might be viewed as part of the need to develop a greener internet.

2. Internet and its Electricity Consumption in Germany Today

The following table provides a first estimate of the current use of the internet and its electricity consumption in Germany. Because of the poor database, several assumptions had to be made. Where no specific data for Germany were available, we adopted the assumptions of Koomey et al. (1999) for the average unit power demand and the weekly hours of use.

Table 1:

Use and electricity consumption of the internet – an estimate for Germany, 2000

	# of units **Millions**	**Use for internet** **hours/week**	**Power demand** **W/unit**	**Electricity consumption** **TWh/year**
Internet users				
PCs at home	4.0	7	200	0.3
PC power users at home	0.7	24	200	0.2
PC home office	1.1	20	200	0.2
PCs at home for all purposes	*5.8*			*0.7*
PC @ office	4.8	7	200	0.4
PCs at office behind firewall[a]	0.7	70	200	0.5
PCs used in commercial internet service support	0.1	50	400	0.1
PCs in offices for all purposes	*5.7*			*1.0*
Subtotal	**11.5**			**1.7**
Internet information suppliers				
Major dot-com companies	0.0	168	19200	0.8
Web server	0.6	168	297	0.3
Subtotal	**0.6**			**1.1**
Network				
Routers on Internet	0.3	168	274	0.7
Routers in LANS and WANs	0.1	168	46	0.1
Telephone central offices	0.0	168	54795	0.7
Subtotal	**0.4**			**1.4**
TOTAL				**4.2**

a: a firewall is a software protection against online attacks

Source: Wuppertal Institute (own calculations), adapted from Koomey et al. 1999

There is a good knowledge of the total number of Internet users in offices and at home: today about 5.8 million private users and about the same number of office users are online. The actual online hours of these users as well as the power needs of the equipment, however, have to be estimated. Here we take the numbers from the USA, since Koomey et al. (1999; 2000) have collected a good database. This means that typical PCs use about 200 Watts when being online, which is a rather conservative, i.e. in this case, high estimate, compared to European measurements. Dreier et al. (2000) estimated a mere 120 W for a Pentium PC including a 14" monitor. Most private users use the Internet for about 7 hours per week. Only one out of eight users is a "power user", who is online about four hours/day and six days of the week. Slightly higher is the number of internet-connected PCs in home offices; they are estimated to be online four hours/day and five working days a week. In offices, the majority of users are also only online for a few hours a day.

These numbers and structures are derived from the situation in the USA. Therefore, use in Germany, where the internet is not yet as widely used as in the USA, could be lower. This is especially true for the percentage of power users and home offices. On the other hand, the share of high intensity users is probably higher among the smaller share of households in Germany than in the US. Furthermore, in the US, probably more people that do have internet access hardly use it. Since these uncertainties are going in both directions, we will take the above results of our calculations as a first estimate. This provides some feeling of the total numbers but could be quite imprecise regarding single details.

Our calculations result in the estimate that **German internet use today is responsible for about 4.2 TWh of electricity consumption per year**. Although every single unit is of low energy intensity, the numerous PCs in offices and at home use about 40 % of the internet electricity. Roughly a quarter is used by services offered via internet (e.g., E-commerce), and about a third by the network infrastructure itself. In terms of greenhouse gases, the **electricity demand of the internet is responsible for about 2.5 million of tons of CO_2 emissions**. This is equivalent to the emissions of a city of about 230,000 inhabitants, or to a little less than 0.3 % of the current German CO_2 emissions.

We did not include the energy to produce all the PCs and servers, because we think that they would be produced also in the absence of the internet. This energy demand is, however, not negligible: it can represent between 15 % (Koomey et al., 1999) and 80 % (Dreier et al., 2000) of the energy use during use.

Neither did we calculate the positive effects cited by Romm (1999) for the USA. Aebischer and Huser (2000) have estimated the net benefit of e-commerce for Switzerland. According to their findings, e-commerce is probably reducing overall primary energy demand, but only by ca. 10 % of the direct energy use from the internet. It seems therefore that it is possible to neglect both the energy to produce the internet equipment, and the energy savings through the internet, particularly since these two quantities appear to level each other out. We will thus concentrate on the use phase of the internet equipment.

3. Trends in the Electricity Use of the Internet

The development of the internet is still in its early days and is strongly connected to the expected future growth of e-commerce. Various media that nowadays exist side by side, such as TV and telecommunications, will at least partly amalgamate with the internet. And the remote control of household appliances ("intelligent home" systems) for supervising and managing the complete technical equipment in the home via internet will become more and more part of everyday life.

The number of internet users in Germany is growing by about 50% every six months. According to estimates of the „Internet Initiative D21“, by the end of 2003 there will be around 60 million internet users. The year 2010 might already see a saturation for internet access with 95% of all households being online (number of households in Germany: 37,5 million), 80% with PCs and 15% with newly developed digital TV reception platforms[1]. For the office sector, including home offices, we estimate a doubling of internet access units by 2010. The following table provides an overview of these figures, the electricity demand of the equipment and the internet hours of users as estimated by Koomey et al. 1999. In Germany, we estimate these figures to apply for 50% of the PC users. We further assume that in 2010 more users will stay online all the time and calculated with 168 hours for the other 50%. This would be a major cultural shift for German PC users, who today usually turn off their PCs when not in use. However, the use of the PC as a server for the remote control of appliances or for "intelligent home" implies continuous use of the PC.

1 PCs and digital TV reception platforms (DTRPs) will compete with each other for the supply of internet access to the home, so there is a large uncertainty as to the share of these two systems: it may well be 40 % PC and 55 % DTRPs. However, the electricity consumption figures for the stand-by mode that enables communication with the internet are quite similar for both ways of access, so for the purpose of scenarios, the uncertainty is much smaller.

Table 2:

Use and electricity consumption of the internet – basic assumptions for Germany, 2010

		W/unit			**hours of use / week**	
	Numbers of units in millions	**CPU**	**Monitor**	**Disk drives, fan etc.**	**for 50% of all users**	**for the other 50% of all users**
PCs at home	27,0000	40	90	70	7	168
PC power users at home	3,0000	40	90	70	24	168
PC home office	2,2634	40	90	70	20	168
PCs at office	9,6195	40	90	70	7	168
PCs at office behind firewall	1,4146	40	90	70	70	168
PCs used in comml internet service support	0,2829	80	120	200	50	168
PCs in offices for all purposes	***11,3171***					
PCs at home for all purposes	***32,2634***					
digital TV platforms equipped for Internet	**5,63**	200 (incl. TV and Modem)			7	

A calculation of the corresponding energy consumption is shown in the table below. To calculate the effect of different users' behaviour, hardware settings and hardware efficiency, the following assumptions were made:

- 50% of all PC users switch off completely if they do not use the PC,
- for the other 50%, who keep their PC always online, we assumed different technical/behavioural options, characterising different scenarios of future electricity use, and showing the potentials for policy action:
- **case 1a:** the user only switches the monitor off, if he/she does not actively use the PC (a saving of 90W);
- **case 1b:** in addition, the user has enabled Power Management of the CPU and peripherals, saving approximately 30 % at current efficiency of Power Management Systems;
- **case 1c:** in addition to case 1b, the stand-by or sleep mode of the new "Energy Star" requirements is used at night and during weekends, with a stand-by consumption of 15W while enabling internet communication;
- **case 1d:** same as 1c but with a lower stand-by consumption of 5W (Intel is developing such units; this value is also reached by a number of units that enable

communication in the "off" mode and meet the requirements of the German "Blue Angel" label, cf. the policy paper on Eco-Labelling in Germany/Europe)

- **case 1e:** Stand-by deep sleep mode of 5W enabling internet communication always when not in active use, i.e. also during the day.

Table 3:

Use and electricity consumption of PCs for the internet – scenarios for Germany, 2010

PC	50%	The other 50% (always online)				
Scenario/case		1a	1b	1c	1d	1e
	TWh	TWh	TWh	TWh	TWh	TWh
PCs at home	0.98	13.41	9.52	4.39	3.56	1.55
PC power users at home	0.37	1.61	1.18	0.61	0.51	0.43
PC home office	0.24	1.19	0.87	0.44	0.37	0.28
PCs at office	0.35	4.78	3.39	1.56	1.27	0.55
PCs at office behind firewall	0.51	0.91	0.71	0.44	0.40	0.53
PCs used in comml internet service support	0.15	0.39	0.29	0.13	0.12	0.15
PCs in offices for all purposes	*1.01*	*6.08*	*4.39*	*2.13*	*1.78*	*1.24*
PCs at home for all purposes	*1.59*	*16.22*	*11.57*	*5.43*	*4.44*	*2.26*
Total	2.60	22.30	15.95	7.56	6.22	3.49
Total for all PCs		24.90	18.55	10.25	8.82	6.09

Total on-mode consumption for internet purposes is 5.2 TWh/a in all scenarios. The remainder is stand-by consumption for internet purposes.

The digital TV platforms have been calculated assuming stand-by consumption attributable to internet access of 20W (case 2a) or 5W (case 2b). It should be borne in mind that these figures relate to only 15% of the households, for which the digital TV platform provides their internet access, and only to that part of the stand-by consumption that is attributable to internet access. However, **total electricity consumption of such digital TV platforms could be very high**, as shown in Annex 1. In Germany it could amount to 16.6 TWh/a with 38 million households, more than 12 % of the household electricity consumption forecast for 2010, or around 3 % of the total electricity consumption forecast. With a consistent policy trying to limit the stand-by consumption of such digital TV platform, this could be contained to just 3 TWh/a, i.e. 13.6 TWh/a could be saved (Annex 1).

Table 4:

Use and electricity consumption of digital TV platforms for the internet – scenarios for Germany, 2010

Digital TV platforms; scenario	**2a**	**2b**
	TWh	**TWh**
During using hours	0,41	0,41
Standby	0,94	0,24
Sum	**1,35**	**0,65**

Concerning the **internet infrastructure**, it is plausible to assume that internet information suppliers and network components will not grow proportionally to the number of users because the capacity of each component will increase. Energy efficiency will improve as well. Nevertheless it is likely that energy consumption of the internet infrastructure will double until 2010. This means that the electricity consumption of the internet-based information and e-commerce suppliers will be **2,16 TWh/a** in 2010, and of the network infrastructure itself **2,83 TWh** as a baseline scenario. With enhanced efforts in energy efficiency, it may be possible to keep the electricity consumption at today's levels.

The development of the **UMTS networks** for mobile phones will also lead to new possibilities of the internet. At the moment, however, the energy consumption of the future UMTS infrastructure is far from clear. One rough calculation has come to **0.35 TWh/a** for one network (based on Schäfer/Weber, 2000). It is also unclear how many UMTS networks will be installed and which part of it can be charged for the Internet. In summer 2000, six UMTS licenses have been auctioned in Germany. If all of these providers would develop their own UMTS network, and all of the electricity consumption was attributed to the internet, this would lead to a maximum consumption of **2.1 TWh/a**.

The electricity consumption of the **mobile phone end users** is likely to be negligible. Schäfer/Weber (2000) found an average stand-by of the battery chargers of today's mobile telephones of 0.05 W, and less than 1 W during use, so that the annual consumption is less than 1 kWh per user. Even if all 80 million Germans used UMTS phones for mobile internet access, the total annual consumption would likely be **below 0.1 TWh/a.**

Another possible driver of electricity use of IT technology is the remote control of home appliances via internet, or of using the PC as a server for an **intranet** ("**intelligent home**"). If we assume that this PC server is already covered by the internet PC calculations above, we have to add an estimate of electricity demand for the communications interfaces inside the household appliances. A typical value would be 3 W for today's technology, and 1 W for units with a switch-mode power supply. These two values indicate the room for policy action. Furthermore, we have assumed that not more than half of all the appliances in the table would be connected to an "intelligent home" system.

Table 5:

Electricity consumption of household appliances for the internet – scenarios for Germany, 2010

Household appliances (50% of all units connected)				
		Saturation	At 3W/unit	At 1W/unit
			TWh/a	TWh/a
Cooker		85,00%	0,4188	0,1396
Refrigerator		80,00%	0,3942	0,1314
Fridge-freezer		40,00%	0,1971	0,0657
Freezer		60,00%	0,2957	0,0986
Dish-washer		45,00%	0,2217	0,0739
Clothes-washer		87,00%	0,4287	0,1429
Washer-dryer		20,00%	0,0986	0,0329
Tumble-dryer		30,00%	0,1478	0,0493
Extraction hood		51,00%	0,2513	0,0838
Microwave		47,00%	0,2316	0,0772
Lighting		100,00%	0,4928	0,1643
Circulation pump		30,00%	0,1478	0,0493
Total			3,3261	1,1087

This extra consumption does not appear to be high compared to that of the PCs. **However, it may well be underestimated**. For example, we did not assume any higher use frequency or extra hours of use. There is ample room for such assumptions, e.g., extra TV/PC screens in more rooms, driven by the central server, for keeping food warm, or because the washing machine remains in a stand-by mode for several hours after the remote-controlled wash has ended. Furthermore, if not one but 30 light sources per home are controlled, this alone would add **5 to 15 TWh/a** (at 1 W and 3 W per light source, respectively) to the German electricity balance.

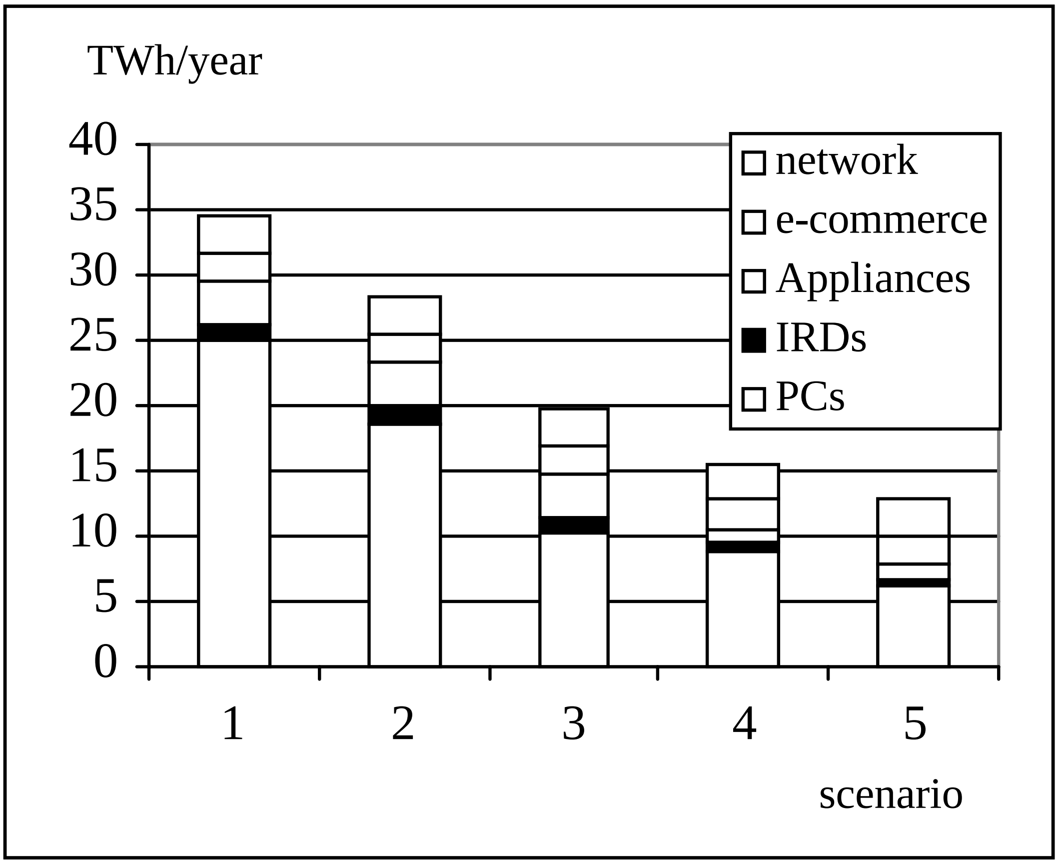
4. Summary and Conclusions

Our above results should be seen as a first estimate. They show that today's power need of internet in Germany sums up to approximately **4.2 TWh/a –** the production of one big coal power station of 600 MW running almost around the clock.

Representing less then one percent of Germany's total electricity consumption, the internet does not seem to be very relevant today. However, the expected **explosion of internet use** during the coming five to ten years **could change the situation dramatically**. Under the assumption of today's technologies and efficiency, this number could increase more than eightfold. The internet would then consume **about 35 TWh/a**, and emit about 20 million tons of CO_2 in Germany alone, i.e. more than 6 % of today's electricity consumption, and 2.5 % of Germany's CO_2 emissions.

However, as the following graph demonstrates, there is ample room for policy action to improve the energy efficiency of the PCs, digital TV platforms (IRDs), and appliances that constitute the internet. This would restrict the electricity use of the internet itself to about 13 TWh/a and would **save 22 TWh/a or 4 % compared to the baseline**.

Figure 1: Scenarios of the electricity consumption of the internet in Germany in 2010



The scenarios 1 to 5 in figure 1 are combinations of the cases for PCs, digital TV platforms, and appliances, which were described in Chapter 3, combined as follows:

Scenario 1: Case 1a for the PCs, case 2a for the digital TV platforms, and 3W per household appliance

Scenario 2: Case 1b for the PCs, case 2a for the digital TV platforms, and 3W per household appliance

Scenario 3: Case 1c for the PCs, case 2a for the digital TV platforms, and 3W per household appliance

Scenario 4: Case 1d for the PCs, case 2b for the digital TV platforms, and 1W per household appliance

Scenario 5: Case 1e for the PCs, case 2b for the digital TV platforms, and 1W per household appliance

The analyses clearly demonstrate that the energy consumption of the final users is the main problem, showing the biggest growth rates in equipment and use. By contrast, expanding commercial use and growing needs for connection services can largely be compensated by more powerful and efficient technology.

These projections assume that the performance of the equipment stays at today's levels. Optimising the equipment of the private and office user, use of power management etc. has the potential to **save up to 85 % of electricity consumption** of an intensive user. If **industry, politics and consumer organisations** would take the huge savings potentials into the households, this would reduce the increase of the internet's power usage and slow down emission growth.

This would require a **policy target** for PCs and digital TV platforms of **not more than 5 W** for internet communication (including the monitor/screen) while not in active use, i.e. in the "sleep"/"stand-by" or "off" modes, and intranet communication with **less than 1 W per unit**. "On" mode consumption should be reduced as well by intelligent power management, notebook technology and LED screens.

If all the available energy efficiency possibilities would be used, **Germany could be online for a total of just over 2 percent of the electricity consumption**, causing CO_2 emissions of about 8 million tons. Similar potentials for policy action exist both for the total stand-by consumption of digital TV platforms and of the intranet in the home ("intelligent home"). By 2010, digital TV platforms could consume 16.6 TWh/a or just 3 TWh/a in Germany - a saving of 13.6 TWh/a is possible through co-ordinated action of manufacturers and policy.

Aebischer and Huber (2000) have analysed the impacts for electricity consumption of **"intelligent home"** technology for Switzerland. Taking all such additional uses into account, their **maximum use scenario** leads to an additional electricity consumption of 5 TWh/a for Switzerland, or 1,430 kWh/year per household. Extending this scenario of Aebischer and Huber to Germany (38 million households) would mean an electricity consumption of **54 TWh/a**, equivalent to 10 % of the total or 40 % of residential electricity consumption. For the EU (160 million households), this scenario would mean an electricity consumption of ca. 230 TWh/a. Again, much of this could be saved through improved low-voltage power supplies, better power management of appliances and servers, a central low-voltage power supply of the intranet, and through more efficient TV/computer screens.

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Annex 1: Digital Television Reception Platforms - another important subject for energy efficiency policy until 2010

At the second International Conference on Energy Efficiency in Household Appliances and Lighting, held in Naples, 27-29 September, 2000, a paper was presented that estimated the technical and energy efficiency development of Digital Television Reception Platforms (DTRP), also called Integrated Receiver Decoders (IRDs).

The paper first looked at the present first generation of IRDs that provide just digital TV reception. Standby losses in this case have already been reduced substantially, from 34 W in 1995 models to an average of 16 W in 2000 and a best practice of 12 W. The average power consumption of the IRD-set-top boxes sold in Germany is 16 to 18 W, as measured by Stiftung Warentest.

Furthermore, on the EU level, negotiations taking place to create a voluntary code of practice by 2003/2004, with an electric power consumption level of 9W in the stand-by active mode.

However, the trend tends towards making the DTRP an integrated communication platform, including, e.g., internet, intranet linking household appliances and other controls, cordless phone, etc. Therefore, the following features with their respective consumption might be added to the DTRP:

- The quadruple LNB would provide four channels (TV receiver, internet receiver, disk, and an open channel for connection to other boxes in the house) instead of the single TV receiver channel of the present IRD boxes; this would roughly double stand-by power.
- The dual tuner requirement would add 3 to 5 W.
- The processor and memory requirement would add PC functions, and perhaps considerable stand-by consumption. However, the authors of the paper expect that PC notebook technology is likely to be used, with much lower stand-by power.
- A hard disk drive might consume at least 6 W, but it might in the long term replace VCR and DVD.
- A wireless interface might consume an additional 3 to 5 W, but would replace the present cordless phone, which on average in the UK consumes 6W.
- A modem would add a few W.

Taken together, if neither care is taken for energy efficiency of the components, nor for power management, it is likely that an integrated DTRP with all these functions would use at least 40 W of stand-by power continuously. With over 160 million households in the EU, and assuming that virtually every household will have a DTRP with a 50 W consumption in 2010, this would add ca. 74 TWh/year of electricity consumption or 10 % of the forecast household electricity consumption in 2010. For Germany, the figures would amount to 16.6 TWh/year with 38 million households, more than 12 % of the household electricity consumption forecast for 2010, or ca. 3 % of the total electricity consumption forecast.

Average electric power consumption of the same DTRP, however, could be as low as 9 W in 2010. This could be achieved with more efficient components, and particularly with an intelligent power management, which achieves that each function uses 0 or at least below 1 W when it is not used.

These savings of 41 W per appliance would result in overall potential electricity savings compared to the technology baseline of 57 TWh/year in the whole EU, and 13.6 TWh/year in Germany. Furthermore, these appliances would replace other stand-by consumption existing today, like that caused by cordless phones or VCRs. There is thus an enormous potential for joint and co-ordinated action by industry and policy in the EU and the Member States as well as worldwide.

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